Plans For New Reactors Worldwide

(*March 2008*)

- **Nuclear power capacity worldwide is increasing steadily but not dramatically, with about 30 reactors under construction in 12 countries.**
- **Most reactors on order or planned are in the Asian region, though plans are firming for new units in Europe, the USA and Russia.**
- **Significant further capacity is being created by plant upgrading.**
- **Plant life extension programs are maintaining capacity, in USA particularly.**

Today there are some 439 nuclear power reactors operating in 30 countries plus Taiwan, with a combined capacity of about 370 GWe. In 2006 these provided 2658 billion kWh, about 16% of the world's electricity.

About 34 power reactors are currently being constructed in 11 countries (see Table below), notably China, South Korea, Japan and Russia.

The International Atomic Energy Agency has significantly increased its projection of world nuclear generating capacity. It now anticipates at least 60 new plants in the next 15 years, making 430 GWe in place in 2020 - 130 GWe more than projected in 2000 and 16% more than actually operating in 2006. The change is based on specific plans and actions in a number of countries, including China, India, Russia, Finland and France, coupled with the changed outlook due to the Kyoto Protocol. This would give nuclear power a 17% share in electricity production in 2020. The fastest growth is in Asia.

It is noteworthy that in the 1980s, 218 power reactors started up, an average of one every 17 days. These included 47 in USA, 42 in France and 18 in Japan. The average power was 923.5 MWe. So it is not hard to imagine a similar number being commissioned in a decade after about 2015. But with China and India getting up to speed with nuclear energy and a world energy demand double the 1980 level in 2015, a realistic estimate of what is possible might be the equivalent of one 1000 MWe unit worldwide every 5 days.

See also *Nuclear Renaissance* paper for the factors driving the increase in nuclear power capacity.

Increased Capacity

Increased nuclear capacity in some countries is resulting from the uprating of existing plants. This is a highly cost-effective way of bringing on new capacity.

Numerous power reactors in USA, Belgium, Sweden and Germany, for example, have had their generating capacity increased. In **Switzerland**, the capacity of its five reactors has been increased by 12.3%. In **the USA**, the Nuclear Regulatory Commission has approved 110 uprates totalling 4900 MWe since 1977, a few of them "extended uprates" of up to 20%.

Spain has a program to add 810 MWe (11%) to its nuclear capacity through upgrading its nine reactors by up to 13%. For instance, the Almarez nuclear plant is being boosted by more than 5% at a cost of US$ 50 million. Some 519 MWe of the increase is already in place.

Finland Finland has boosted the capacity of the Olkiluoto plant by 29% to 1700 MWe. This plant started with two 660 MWe Swedish BWRs commissioned in 1978 and 1980. It is now licensed to

operate to 2018. The Loviisa plant, with two VVER-440 (PWR) reactors, has been uprated by 90 MWe (10%).

Sweden is uprating Forsmark plant by 13% (410 MWe) over 2008-10 at a cost of EUR 225 million, and Oskarshamn-3 by 21% to 1450 MWe at a cost of EUR 180 million.

Nuclear Plant Construction

Most reactors currently planned are in the Asian region, with fast-growing economies and rapidly-rising electricity demand.

Some 16 countries with existing nuclear power programs (Argentina, Brazil, Bulgaria, Canada, France, Russia, China, India, Pakistan, Japan, Romania, Slovakia, South Korea, South Africa, Ukraine, USA) have plans to build new power reactors (beyond those now under construction).

In all, over 90 power reactors with a total net capacity of almost 100,000 MWe are planned and over 200 more are proposed. Rising gas prices and greenhouse constraints on coal have combined to put nuclear power back on the agenda for projected new capacity in both Europe and North America.

In the **USA** there are proposals for over twenty new reactors and the first combined construction and operating licences for these have been applied for. All are for late third-generation plants, and a further proposal is for two ABWR units.

In Canada there are plans to build up to 3500 MWe of new capacity in Ontario, and proposals for similar capacity in Alberta and one large reactor in New Brunswick.

In **Finland**, construction is now under way on a fifth, very large reactor which will come on line in 2011 and plans a re firming for another large one to follow it.

France is building a similar 1600 MWe unit at Flamanville, for operation from 2012.

Romania's second power reactor istarted up in 2007, and plans are being finalised for two further Canadian units.

Slovakia is completing two 470 MWe units at Mochovce, to operate from 2011-12.

Bulgaria is about to start building two 1000 MWe Russian reactors at Belene.

In **Russia**, five large reactors are under active construction and due for completion by 2012, one being a large fast neutron reactor. Seven further reactors are then planned to replace some existing plants, and by 2015 ten new reactors totalling at least 9.8 GWe should be operating. Further reactors are planned to add new capacity by 2020. This will increase the country's present 21.7 GWe nuclear power capacity to 50 GWe about 2020. In addition about 5 GW of nuclear thermal capacity is planned. A small floating power plant is expected to be completed by 2011 and another by 2020.

Poland is planning some nuclear power capacity but initially is likely to join a joint project in Lithuania, with Estonia and Latvia.

Nuclear power will continue to play a major role in the future electricity supply mix in both South Korea and Japan.

South Korea plans to bring a further eight reactors into operation by the year 2015, giving total new capacity of 9200 MWe. Ulchin 5 & 6 were connected to the grid in 2004. Following them are planned Shin-Kori-1 & 2 and Wolsong-5 & 6, to be improved OPR-1000 designs. Then come Shin-Kori-3 & 4 and Shin-Ulchin 1&2, the first of the Advanced PWRs of 1400 MWe, to be in operation by 2016. These APR-1400 designs have evolved from a US design which has US NRC design certification, and have been known as the Korean Next-Generation Reactor.

Japan has two reactors under construction and another ready to start building. It also has plans and, in most cases, designated sites and announced timetables for a further 10 power reactors, totalling over 13,000 MWe which are expected to come on line 2012-18.

In **China**, now with eleven operating reactors on the mainland, CNNC is well into the next phase of its nuclear power program. The second of two Russian 1000 MWe PWRs at Tianwan in Jiangsu province was grid connected in May 2007.

China NNC and Guangdong NPC have six more indigenous reactors under construction at Lingdong, Qinshan, Hongyanhe and Ningde. Ten more are due to start construction by July 2010 at these sites plus Yangjiang. Four large Western third-generation ones are due to start construction at Sanmen and Haiyang, with two more at Taishan. China aims to quadruple its nuclear capacity from that operating and under construction by 2020. The Shidaowan high temperature gas-cooled reactor will start construction in 2009 at Rongcheng , Shandong province.

On Taiwan, Taipower is building two advanced BWRs at Lungmen.

India has six reactors under construction and expected to be completed by 2010. This includes two large Russian reactors and a large prototype fast breeder reactor as part of its strategy to develop a fuel cycle which can utilise thorium. Further units are planned.

Pakistan has a second 300 MWe reactor under construction at Chasma, financed by China. There are plans for more Chinese power reactors.

In **Kazakhstan**, a joint venture with Russia's Atomstroyexport envisages development and marketing of innovative small and medium-sized reactors, starting with a 300 MWe Russian design as baseline for Kazakh units.

In Iran nuclear power plant construction was suspended in 1979 but in 1995 Iran signed an agreement with Russia to complete a 1000 MWe PWR at Bushehr. Construction is well advanced.

The Turkish government plans to have three nuclear power plants total 4500 MWe operating by 2012-15, a US$ 10.5 billion investment.

Indonesia plans to start constructing a 2000 MWe nuclear power station in 2010.

Vietnam is also considering its first nuclear power venture, to be commissioned by 2017.

Fuller details of all the above contries curently without nuclear power are in country papers or the paper on *Emerging Nuclear Energy Countries.*

Plant Life Extension

Most nuclear power plants originally had a nominal design lifetime of up to 40 years, but engineering assessments of many plants over the last decade has established that many can operate longer. In the USA nearly 50 reactors have been granted licence renewals which extend their operating lives from the original 40 out to 60 years, and operators of most others are expected to apply for similar extensions. In Japan, plant lifetimes up to 70 years re envisaged.

When the oldest commercial nuclear power stations in the world, Calder Hall and Chapelcross in the UK, were built in the 1950s they were very conservatively engineered, though it was assumed that they would have a useful lifetime of only 20-25 years. They were then authorised to operate for 50 years but due to economic factors closed earlier. Most other Magnox plants are licensed for 40-year lifetimes.

The Russian government in 2000 extended the operating lives of the country's 12 oldest reactors from their original 30 years, for 15 years.

The technical and economic feasibility of replacing major reactor components, such as steam generators in PWRs and pressure tubes in CANDU heavy water reactors, has been demonstrated. The possibilities of component replacement and licence renewals extending the lifetimes of existing plants are very attractive to utilities, especially in view of the public acceptance difficulties involved in constructing replacement nuclear capacity.

On the other hand, economic, regulatory and political considerations have led to the premature closure of some power reactors, particularly in the United States, where reactor numbers have fell from 110 to 103, and in eastern Europe.

Power reactors under construction, or almost so

Start Operation*		REACTOR	TYPE	MWe (net)
2008	India, NPCIL	Rawatbhata 5	PHWR	202
2008	India, NPCIL	Kaiga 4	PHWR	202
2008	India, NPCIL	Kudankulam 1	PWR	950
2008	Iran, AEOI	Bushehr 1	PWR	950
2009	India, NPCIL	Rawatbhata 6	PHWR	202
2009	Canada, Bruce Power	Bruce A1	PHWR	769
2009	Russia, Rosenergoatom	Volgodonsk 2	PWR	950
2009	Japan, Hokkaido	Tomari 3	PWR	912
2009	China, Taipower	Lungmen 1	ABWR	1300
2009	India, NPCIL	Kudankalam 2	PWR	950
2010	Canada, Bruce Power	Bruce A2	PHWR	769
2010	Korea, KHNP	Shin Kori 1	PWR	1000
2010	India, NPCIL	Kalpakkam	FBR	470
2010	China, CGNPC	Lingao 3	PWR	1080
2010	China, Taipower	Lungmen 2	ABWR	1300
2010	Argentina, CNEA	Atucha 2	PHWR	692

2010	Russia, Rosenergoatom	Severodvinsk	PWR x 2	70
2011	Finland, TVO	Olkilouto 3	PWR	1600
2011	Russia, Rosenergoatom	Kalinin 4	PWR	950
2011	Korea, KHNP	Shin Kori 2	PWR	1000
2011	Korea, KHNP	Shin Wolsong 1	PWR	1000
2011	China, CNNC	Qinshan 6	PWR	650
2011	China, CGNPC	Lingao 4	PWR	1080
2011	Pakistan, PAEC	Chashma 2	PWR	300
2011	Russia, Rosenergoatom	Kursk 5	RBMK	1000
2012	China, CNNC	Qinshan 7	PWR	650
2012	Korea, KHNP	Shin Wolsong 2	PWR	1000
2012	France, EdF	Flamanville 3	PWR	1630
2012	Russia, Rosenergoatom	Beloyarsk 4	FBR	750
2012	Japan, Chugoku	Shimane 3	PWR	1375
2012	Russia, Rosenergoatom	Novovoronezh 6	PWR	1070
2012	Slovakia, SE	Mochovce 3	PWR	440
2012	China, CGNPC	Hongyanhe 1	PWR	1080
2012	China, CGNPC	Ningde 1	PWR	1080
2013	China, CNNC	Sanmen 1	PWR	1100
2013	China, CGNPC	Ningde 2	PWR	1080
2013	Russia, Rosenergoatom	Leningrad 5	PWR	1070
2013	Russia, Rosenergoatom	Novovoronezh 7	PWR	1070
2013	Korea, KHNP	Shin Kori 3	PWR	1350
2013	China, CGNPC	Hongyanhe 2	PWR	1080
2013	China, CGNPC	Yangjiang 1	PWR	1080
2013	Japan, EPDC/J Power	Ohma	ABWR	1350
2013	Japan, Tepco	Fukishima I-6	ABWR	1350
2013	Slovakia, SE	Mochovce 4	PWR	440
2014	China , CNNC	Sanmen 2	PWR	1100
2014	China , CPI	Haiyang 1	PWR	1100
2014	China , CGNPC	Ningde 3	PWR	1080
2014	China , CGNPC	Yangjiang 2	PWR	1080
2014	China , CGNPC	Hongyanhe 3	PWR	1080
2014	Korea, KHNP	Shin-Kori 4	PWR	1350
2014	Romania, SNN	Cernavoda 3	PHWR	655
2014	Bulgaria, NEK	Belene 1	PWR	1000
2014	Russia , Rosenergoatom	Leningrad 6	PWR	1200

2014	Russia , Rosenergoatom	Volgodonsk 3	PWR	1200
2014	Japan , Tepco	Fukishima I-7	ABWR	1080
2014	Japan , Tepco	Higashidori 1	ABWR	1080

* Latest announced year of proposed commercial operation.
† grid connected.

The World Nuclear Power Reactor table gives a fuller and (for current year) possibly more up to date overview of world reactor status.

Some power reactors planned or on order

Start operation	Start construction	Reactor		Type	MWe (each)
2015	2008	Bulgaria, NEK	Belene 2	PWR	1000
2016	2010	Japan, Tepco	Higashidori 2 (Tepco)	ABWR	1320
2013-14	2010	Japan, JAPC	Tsuruga 3 & 4	APWR	1500
2014/16	2009	Japan, Chugoku	Kaminoseki 1	ABWR	1373
2016-17		Korea, KHNP	Shin-Ulchin 1-2	APR-1400	1350
2014	2011	Japan, Tohoku	Higashidori 2 (Tohoku)	ABWR	1320
2015		Slovenia, NEK	Krsko 2	PWR?	1000?

Dates according to latest announcements.

Sources:
UIC/WNA information papers and newsletters.
Nuclear Engineering International, handbook.